



THEORETICAL FOUNDATIONS OF DEVELOPING ENGINEERING THINKING AND CREATIVE PROBLEM-SOLVING THROUGH ROBOTICS IN PRESCHOOL EDUCATION

Ismoilova Gulmira Erkin Qizi

Master's Student at Termez State Pedagogical Institute

Orcid: 0009-0004-9612-6077

Annotation: This study explores the theoretical foundations for fostering engineering thinking and creative problem-solving skills in preschool children through robotics education. Robotics, as an interdisciplinary approach, integrates science, technology, engineering, and mathematics (STEM) concepts, providing young learners with hands-on experiences that stimulate cognitive development, creativity, and logical reasoning. The research emphasizes the significance of early exposure to technological tools and interactive learning environments in shaping critical thinking and innovative capacities. The theoretical analysis highlights educational strategies, developmental psychology principles, and pedagogical approaches that support the introduction of robotics in early childhood settings. This work serves as a basis for designing curricula and activities that encourage problem-solving, experimentation, and the development of engineering skills from a young age.

Keywords: Preschool education, robotics, engineering thinking, creative problem-solving, STEM education, cognitive development, early childhood learning, pedagogical methods, innovation, interactive learning.

In the rapidly evolving technological world, equipping children with problem-solving skills, creativity, and engineering thinking from an early age has become a pressing educational priority. Preschool education, traditionally focused on social, emotional, and basic cognitive development, now increasingly incorporates innovative tools to foster advanced cognitive competencies. Robotics education, in particular, provides a unique platform where young children can engage with mechanical systems, programming concepts, and logical tasks in a tangible, interactive manner.

Engineering thinking, which encompasses analytical reasoning, system design understanding, and iterative problem-solving, can be nurtured even in preschool-aged learners through structured activities that emphasize exploration, experimentation, and trial-and-error learning. When combined with creative problem-solving, robotics activities encourage children to generate novel ideas, evaluate alternatives, and



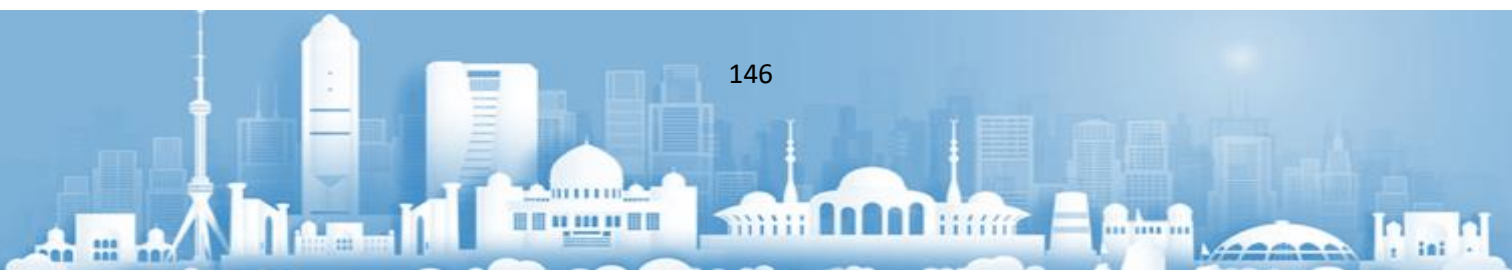


implement solutions in collaborative settings. These experiences contribute not only to cognitive development but also to social, emotional, and collaborative skills.

In recent years, the integration of robotics into preschool education has gained significant attention among educators and researchers worldwide. Early childhood represents a critical period for cognitive, emotional, and social development, during which children acquire foundational skills that influence their lifelong learning trajectory. Introducing engineering thinking and creative problem-solving at this stage is not only feasible but also highly beneficial, as preschoolers exhibit natural curiosity, imaginative capacity, and a propensity for exploratory learning. Robotics provides a unique interdisciplinary platform that combines elements of science, technology, engineering, and mathematics (STEM) with hands-on, interactive experiences tailored to young learners.

Engineering thinking in preschool children involves the ability to analyze problems, identify patterns, understand systems, and apply logical reasoning to develop solutions. Contrary to common misconceptions, children as young as four to six years old can engage in simple engineering tasks when these are appropriately scaffolded and presented through play-based, interactive methods. Research by Bers (2018) demonstrates that preschoolers participating in robotics activities can successfully manipulate simple machines, construct basic mechanisms, and sequence actions to achieve specific goals. These experiences foster computational thinking, spatial reasoning, and problem decomposition, which are essential components of early engineering cognition.

Creative problem-solving, on the other hand, entails generating novel ideas, evaluating alternative approaches, and experimenting with different solutions. Preschool robotics activities, such as building and programming a robot to complete a task, encourage divergent thinking and iterative experimentation. Studies indicate that children exposed to structured robotics programs exhibit higher levels of creativity, persistence, and flexibility in problem-solving compared to peers engaged solely in traditional play-based activities. For instance, the work of Alimisis (2013) highlights that integrating robotics kits like LEGO Education WeDo or Bee-Bot in preschool curricula enhances both imaginative exploration and technical reasoning simultaneously. These activities require children to plan, predict outcomes, test hypotheses, and adapt strategies, thereby linking creative thinking directly with tangible engineering experiences.





The theoretical foundations of integrating robotics into preschool education are grounded in constructivist and socio-cultural learning theories. According to Piagetian theory, children construct knowledge through active engagement with their environment, which aligns with robotics tasks that encourage exploration, experimentation, and trial-and-error learning. Vygotsky’s socio-cultural theory further emphasizes the role of social interaction and scaffolding in cognitive development. In the context of robotics, teachers and peers act as facilitators, guiding children through problem-solving processes, prompting reflective thinking, and encouraging collaborative design activities. Collaborative robotics exercises not only enhance technical skills but also promote communication, negotiation, and teamwork, which are essential for social and emotional development in early childhood.

Another critical aspect of robotics in preschool education is its capacity to integrate interdisciplinary knowledge. Activities involving simple coding, motor skills, mechanical assembly, and logical sequencing allow children to make connections across mathematics, science, and technology concepts. For example, constructing a robotic vehicle to move along a designated path introduces early geometry, measurement, and spatial reasoning, while simultaneously engaging children in engineering design principles. These integrative experiences contribute to a holistic development model, where cognitive, social, and creative competencies are cultivated simultaneously. Research by Bers et al. (2014) shows that preschool robotics programs significantly improve children’s understanding of cause-and-effect relationships and enhance their ability to plan and execute multi-step tasks, which are foundational engineering skills.

Moreover, robotics activities can be differentiated to accommodate diverse learning styles and abilities. Visual, kinesthetic, and auditory learners benefit from interactive components, tangible manipulatives, and sound or feedback mechanisms embedded in robotic kits. Adaptive robotics tools enable children with varying developmental levels to participate meaningfully, ensuring equitable access to early STEM education. This inclusivity aligns with contemporary educational goals promoting diversity and accessibility in early childhood learning environments.

The role of teachers in implementing robotics programs is pivotal. Effective facilitation involves designing developmentally appropriate activities, providing guided exploration, and encouraging reflective thinking. Teachers must scaffold tasks to match children’s cognitive abilities, gradually increasing complexity to stimulate problem-solving without causing frustration. Professional development programs for

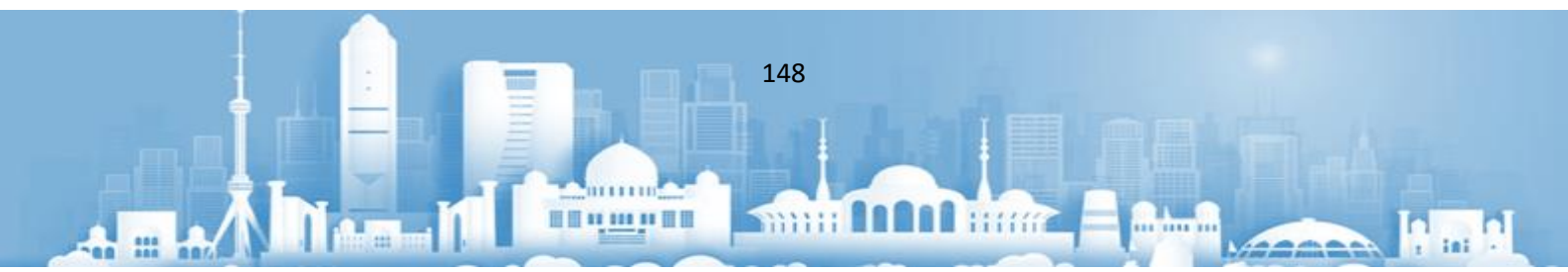


early childhood educators increasingly emphasize integrating robotics and STEM principles into daily learning routines, equipping teachers with the skills to foster both engineering thinking and creative capacities. Furthermore, research by Kafyulilo et al. (2015) underscores the importance of continuous assessment and feedback, allowing educators to monitor progress, identify challenges, and adapt instructional strategies accordingly.

Assessment in preschool robotics education extends beyond traditional academic measures. Observational assessments, portfolio documentation, and performance-based evaluations capture the development of problem-solving strategies, creativity, collaboration, and engineering thinking skills. Such assessments provide a comprehensive understanding of a child’s competencies, highlighting areas of strength and identifying opportunities for further growth. By documenting the iterative processes children employ in robotics tasks, educators gain insight into cognitive strategies, reasoning patterns, and innovative thinking approaches that are otherwise difficult to measure through conventional testing.

The integration of robotics into preschool education also addresses the growing global emphasis on STEM readiness. Early exposure to engineering and technology concepts prepares children for more advanced learning in primary and secondary education. Countries leading in STEM innovation, such as Finland, Singapore, and South Korea, have successfully implemented robotics initiatives in early childhood settings, demonstrating improvements in problem-solving ability, creativity, and computational thinking among young learners. These international practices provide evidence that structured robotics experiences in preschool can serve as a foundation for lifelong learning and innovation.

In conclusion, robotics represents a highly effective medium for developing engineering thinking and creative problem-solving in preschool education. The combination of hands-on activities, interdisciplinary learning, collaborative engagement, and structured reflection fosters a broad range of cognitive, social, and creative skills. Theoretical frameworks from constructivist and socio-cultural perspectives support the pedagogical strategies employed, while empirical evidence confirms the positive impact of robotics programs on young children’s intellectual and creative development. By integrating robotics thoughtfully into early childhood curricula, educators can cultivate future-ready learners equipped with the critical thinking, creativity, and problem-solving skills essential for success in the 21st century.





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